3 Summary of the Baseline Human Health and Ecological Risk Assessment

As a follow-up to the Screening Level Risk Assessment (SLRA) which identified chemicals of potential concern (COPCs), a Baseline Human Health and Ecological Risk Assessment (BLRA) for the Lower Fox River and Green Bay (RETEC, 2002b) has been prepared as a companion document to the RI and FS. This BLRA was undertaken to provide an assessment of risks to human health and the environment that will support the selection of a remedy to eliminate, reduce, or control those risks. Specific goals of the BLRA for the Lower Fox River and Green Bay were to:

- Examine how the COPCs carried forward from the SLRA (RETEC, 1998) move from the sediment and water into humans and ecological receptors within the Lower Fox River and Green Bay.

- Quantify the current (or baseline) human health and ecological risk associated with the COPCs.

- Distinguish those COPCs which pose the greatest potential for risk from those that pose negligible risks to human health and the environment.

- Determine which exposure pathways lead to the greatest risks.

- Determine which COPCs are carried forward in the FS as COCs.

- Support the selection of a remedy to eliminate, reduce, or control identified risks by calculating sediment quality thresholds (SQTs).

The COPCs carried forward from the SLRA included polychlorinated biphenyls (PCBs) (total and selected congeners), dioxins/furans (2,3,7,8-TCDD and 2,3,7,8-TCDF), DDT and its metabolites DDE and DDD, dieldrin, and three metals (arsenic, lead, and mercury). For both assessments, risk was characterized for the four reaches of the Lower Fox River, including Little Lake Butte des Morts, Appleton to Little Rapids, Little Rapids to De Pere, and De Pere to Green Bay (Green Bay Zone 1) as well as the zones of the bay: Zone 2, Zone 3A, Zone 3B, and Zone 4. Therefore, risks between each of these reaches and zones could be compared.

Details of the human health risk assessment and the ecological risk assessment are provided in Sections 3.1 and 3.2, respectively. General conclusions of both assessments were that:

- Fish consumption is the exposure pathway that represents the greatest level of risk for receptors (other than direct risk to benthic invertebrates).

- The primary COC is total PCBs. Other COCs carried forward for remedial evaluation and long-term monitoring are mercury and DDE.

- In general, areas with the greatest risk are Green Bay zones 1 and 2, although for human health, estimated risk did not differ greatly between the river reaches and bay zones.

SQTs were estimated for PCBs with the assumption that a remedial action targeting PCBs would also capture the other COCs. The SQTs themselves are not cleanup criteria, but are a good approximation of protective sediment values and can be considered to be "working values" from which to select a remedial action level. The SQTs and risk associated with SQTs are further evaluated and discussed in Section 8 of this FS. Safe concentrations in fish for human and ecological receptors were determined for:

- Human and ecological receptors (e.g., fish-eating humans, fish, piscivorous birds, and piscivorous mammals);

- Appropriate human health risk levels (10^{-5} for cancer risk in humans and a hazard index (HI) of 1.0 for noncancer risk based on fish consumption), and both the no observed adverse effect concentrations (NOAECs) and lowest observed adverse effect concentrations (LOAECs) for ecological receptors; and

- Two different assumptions regarding fish consumption rates for humans: subsistence fishing and sport fishing.

Once the "safe" PCB fish tissue concentrations were determined, corresponding sediment concentrations that would need to exist in the river or bay were calculated. This was accomplished using a bioenergetic food web model—the FRFood Model. PCB SQTs are the output of the model and are further discussed in Section 3.3. The development and validation of the mathematical model used to define SQTs is described in the BLRA (Section 7) and the FRFood Model Documentation Memorandum (RETEC, 2002c).

The SQTs themselves do not provide specific cleanup goals, but rather provide the resources managers (Wisconsin and federal agencies) an array of risk-based thresholds from which to select remedial action levels for evaluation in the FS. The final selection of the remedial action levels carried forward in the FS is a policy decision left to the response agencies. A summary of the results of the BLRA are presented in the two sections below. In addition, the SQTs are presented in Section 3.3.

3.1 Human Health Risk Assessment

Using the results of the SLRA as its starting point, the human health risk assessment for the Lower Fox River and Green Bay calculated cancer risks and noncancer hazard indices for the following receptors:

- Recreational anglers,
- High-intake fish consumers,
- Hunters,
- Drinking water users,
- Local residents,
- Recreational water users (swimmers and waders), and
- Marine construction workers.

For the human health risk assessment, two evaluations were performed, a baseline risk assessment and a focused risk assessment. For the baseline risk assessment, all data for a specific medium for each COPC were used to evaluate exposures and risks. The highest cancer risks and noncancer hazard indices were calculated for recreational anglers and high-intake fish consumers due primarily to consumption of fish containing PCBs. For the focused risk assessment, which examined only exposure to PCBs in fish by recreational anglers and high-intake fish consumers, and only fish tissue data from 1989 and after were used.

In a follow-up, focused assessment, potential risks to recreational anglers and high-intake fish consumers were examined in more detail. Using fish concentration data from 1990 on (and walleye data from 1989 in Green Bay), the cancer risks were as high as 9.8×10^{-4} for recreational anglers and 1.4×10^{-3} for high-intake fish consumers. These risks are 100 times greater than the 10^{-5} cancer risk level commonly used in Wisconsin according to administrative rules such as Chapter NR 105 Wisconsin Administrative Code for the protection of human health based on fish consumption (Chapter 105 specifies a 10^{-5} risk level for fish consumption). These risks are 1,000 times greater than the 10^{-6} cancer risk level, which is the point at which risk management decisions may be made under Superfund. The highest cancer risks for recreational anglers and high-intake fish consumers are more than 20 times greater than background risks calculated for

eating fish from Lake Winnebago (which is a background location relative to the Lower Fox River and Green Bay).

The hazard indices were as high as 36.9 for the recreational angler and 52.0 for the high-intake fish consumer; far in exceedance of the value of 1.0 established to protect people from long-term adverse noncancer health effects. The noncancer health effects associated with exposure to PCBs include reproductive effects (e.g., conception failure in highly exposed women), developmental effects (e.g., neurological impairment in highly exposed infants and children), and immune system suppression (e.g., increased incidence of infectious disease in highly exposed infants). The highest noncancer hazard indices for recreational anglers and high-intake fish consumers are more than 20 times greater than background hazard indices calculated for eating fish from Lake Winnebago (which is a background location relative to the Lower Fox River and Green Bay).

To provide perspective on the number of individuals who are potentially exposed in the state of Wisconsin, there are on the order of 136,000 registered recreational anglers, and about 5,000 high-intake fish consumers, based on fish licenses and a variety of surveys, respectively. The high-intake fish consumers can include low-income minority anglers, Native American anglers, Hmong/Laotian anglers, and anyone else who consumes an amount of fish consistent with the assumptions used to define a "high-intake fish consumer."

Cancer risks and hazard indices were calculated by river reach and Green Bay zone. However, there was relatively little difference between the highest risk in any reach or zone, which occurred in the Green Bay Zone 3A, and the lowest risk in any reach or zone, which occurred in the Little Rapids to De Pere Reach. The risk in Green Bay Zone 3A is 2.3 times greater than the risk in the Little Rapids to De Pere Reach.

The cancer risks and hazard indices were examined in detail in four species: carp, perch, walleye, and white bass. Carp generally had the highest concentrations of PCBs in each reach or zone where data were available and so exhibited the highest cancer risks and hazard indices. The lowest concentrations of PCBs occurred for perch, walleye, or white bass, depending on the river reach or Green Bay zone. The cancer risks and hazard indices for these three species are comparable.

The only other receptors with cancer risks exceeding 10^{-6} were the hunters and drinking water users. Cancer risks for the marine construction worker slightly exceed the 1×10^{-6} level in the Little Lake Butte des Morts Reach. The risks to the hunter were as high as 8.3×10^{-5}, but were at least 10 times lower than the risks to the anglers. The risk to the hunter was due to ingestion of PCBs in

waterfowl. The risk to drinking water users exceeded 10^{-6} only in the De Pere to Green Bay Reach. This exceedance was due to arsenic in surface water, and the arsenic value was from one detected value in a total of four samples. A more systematic sampling of this water for arsenic might show this single detected value to be anomalous. Additionally, the water in this reach is not currently used as a source of drinking water, and there are no plans to use it as such in the foreseeable future (this reach of the Lower Fox River is not classified for use as a source of drinking water). The cancer risks to drinking water users in all other reaches of the Lower Fox River and zones of Green Bay were below the 10^{-6} level, as were the cancer risks for the local residents and recreational water users (swimmers and waders).

The only other receptors with hazard indices exceeding 1.0 were the hunter, drinking water user, and local resident. The highest HI for these receptors was 3.8, only slightly above 1.0. These hazard indices are more than 10 times lower than the highest hazard indices for the high-intake fish consumers and about 10 times lower than the highest hazard indices for the recreational angler. The hazard indices were below 1.0 for the recreational water users and marine construction workers in all reaches of the Lower Fox River and zones of Green Bay.

In conclusion, recreational anglers and high-intake fish consumers are at greatest risk for contracting cancer or experiencing noncancer health effects. A summary of these risks is presented on Figures 3-1 and 3-2. The highest cancer risks are more than 20 times greater than background risks calculated for eating fish from Lake Winnebago (which is a background location relative to the Lower Fox River and Green Bay). The primary reason for these elevated risks and hazard indices is ingestion of fish containing PCBs.

3.2 Ecological Risk Assessment

As part of the ecological BLRA exposure assessment, assessment endpoints selected for risk evaluation were:

- **Aquatic Invertebrates:** Insects and other invertebrates that live in the water and are important prey items for fish and other insects.

- **Benthic Invertebrates:** Insects and other invertebrates that live in or on the sediment that are important in recycling nutrients and a principal part of fish diets.

- **Benthic Fish:** Fish, such as carp and catfish, that live on and forage in the sediments and are in turn eaten by other fish, birds, mammals, and people.

- **Pelagic Fish:** Fish, such as walleye and yellow perch, that live in the water column, and eat other fish or insects that live in the water or on the sediments. These fish may be in turn eaten by other fish, birds, mammals, and people.

- **Insectivorous Birds:** Birds, such as swallows, that eat insects that hatch from the sediment.

- **Piscivorous Birds:** Birds, such as cormorants or terns, that principally eat fish from the Lower Fox River or Green Bay.

- **Carnivorous Birds:** Birds, such as eagles, that will eat a variety of prey, including fish or small mammals.

- **Piscivorous Mammals:** Mammals, such as mink, that eat fish as an important part of their diet.

Risk was characterized for these assessment endpoints principally based on the calculation of hazard quotients (HQs). HQs are the ratios of measured COPC concentrations in media (water, sediment, tissue) as compared to safe COPC concentrations in these media. HQs that are greater than 1.0 imply that risk may be present. Where available, both NOAEC and LOAEC HQs were calculated. Effects evaluated were reproductive dysfunction, death at birth, or deformities in the surviving offspring. When NOAEC HQs exceeded 1.0, but LOAEC HQs were less than 1.0, then it was concluded that there was potential risk. When both the NOAEC and LOAEC HQs exceeded 1.0, it was assumed that risk was present.

Besides HQs, other factors that were considered in determining risk to assessment endpoints were: field studies, habitat, and population levels. Together, each of the components of the evaluation provided a weight of evidence for the presence or absence of risk.

Risks were evaluated by river reach and bay zone, and are summarized below and on Figures 3-1 through 3-3.

3.2.1 Little Lake Butte des Morts Reach

In summary, the results taken in total suggest that only measured or estimated concentrations of total PCBs are at sufficient levels to cause, risk to benthic

invertebrates, carnivorous birds, and piscivorous mammals. Potential risks from total PCBs are indicated for water column invertebrates, benthic and pelagic fish, insectivorous and piscivorous birds. Measured or estimated concentrations of mercury are found to be at sufficient concentrations to cause or potentially cause risk to water column and benthic invertebrates, and piscivorous birds. Concentrations of 2,3,7,8-TCDD, DDD, and DDT are only sufficient to be of risk to benthic invertebrates. Sediment concentrations of elevated PCBs are widespread and persistent throughout the reach. Concentrations of arsenic, dieldrin, and all o,p'- isomers of DDT and its metabolites are not found to pose risk to any assessment endpoint. While all assessment endpoints are potentially at risk or are at risk based upon HQs from total PCBs, it was concluded on the weight of evidence that only benthic invertebrates, carnivorous birds, and piscivorous mammals are at risk to elevated levels of PCBs.

3.2.2 Appleton to Little Rapids Reach

In summary, the results taken in total suggest that measured or estimated concentrations of total PCBs are at sufficient levels to cause risk to benthic invertebrates, carnivorous birds, and piscivorous mammals. Potential risks are indicated for all other receptors except insectivorous birds, for which there are no data. Measured or estimated concentrations of mercury were found to be at sufficient concentrations to cause or potentially cause risk to benthic invertebrates, piscivorous birds, and carnivorous birds. Concentrations of lead are only of risk to benthic invertebrates. Concentrations of all chlorinated pesticides (dieldrin, o,p'-DDD, o,p'-DDE, o,p'-DDT, p,p'-DDD, p,p'-DDE, p,p'-DDT) are not found to pose risk to any assessment endpoint. Surface sediment concentrations of elevated PCBs indicate reach-wide effects, but are likely limited to specific deposits. Carnivorous birds may have potential risks from PCB exposure, but there do not appear to be any apparent impairments to successful reproduction. Piscivorous mammals are estimated to be at risk to PCBs in this reach.

3.2.3 Little Rapids to De Pere Reach

In summary, the results taken in total suggest that measured or estimated concentrations of total PCBs are at sufficient levels to cause, or potentially cause, risk to benthic invertebrates, carnivorous birds, and piscivorous mammals. Potential risks are indicated for benthic and pelagic fish, and piscivorous birds. There are no data to evaluate insectivorous birds. Measured or estimated concentrations of mercury are found to be at sufficient concentrations to cause, or potentially cause, risk to aquatic invertebrates, benthic invertebrates, pelagic fish, piscivorous birds, and carnivorous birds. Concentrations of arsenic, dieldrin, all o,p'- isomers of DDT and its metabolites, and p,p'-DDD are not sufficient to pose risk to any assessment endpoint. While all fish and birds are potentially at

risk from mercury and total PCBs, only water column and benthic invertebrates and piscivorous mammals are assumed to be at risk, based on elevated HQs.

There are persistent risks to benthic infaunal communities in sediments from exposure to lead, mercury, 2,3,7,8-TCDD, total PCBs, p,p'-DDE, and p,p'-DDT. Surface sediment concentrations of elevated PCBs are fairly uniformly distributed throughout the reach, and thus it is inferred that invertebrate communities are at risk throughout the entire reach. Apparent population level impacts of COCs on reproduction and survival for benthic and pelagic fish are not indicated, although sublethal effects may occur. Carnivorous birds may have sublethal risks from PCB exposure, and because of their status are considered to be at risk. Piscivorous mammals are estimated to be at risk to PCBs in this reach.

3.2.4 De Pere to Green Bay Reach (Green Bay Zone 1)

In summary, the results taken in total suggest that measured or estimated concentrations of total PCBs are at sufficient levels to cause risk to benthic invertebrates and piscivorous mammals. Total PCBs are at sufficient levels to potentially cause risk to aquatic invertebrates and insectivorous birds. Concentrations of dieldrin, all o,p'- isomers of DDT and its metabolites, and p,p'-DDT are not sufficient to pose risk to any of the evaluated assessment endpoints. Measured concentrations of mercury were found to be at sufficient concentrations to cause or potentially cause risk to benthic invertebrates. Risks to fish and birds are discussed in the risk summary for Green Bay Zone 2.

3.2.5 Green Bay Zone 2

In summary, the results taken in total suggest that measured or estimated concentrations of total PCBs are at sufficient levels to cause risks to benthic invertebrates, carnivorous birds, and piscivorous mammals. Potential risks are indicated for benthic and pelagial fish, and piscivorous birds. Measured or estimated concentrations of mercury are at sufficient concentrations to cause or potentially cause risk to aquatic invertebrates, benthic invertebrates, pelagial fish, piscivorous birds, and carnivorous birds. Measured or estimated concentrations of DDE are at sufficient concentrations to cause, or potentially cause, risk to benthic fish, pelagic fish, insectivorous birds, piscivorous birds, and carnivorous birds.

Benthic and pelagial fish populations appear to be relatively robust throughout lower Green Bay, as evidenced by maintenance of self-reproducing populations of benthic fish and the reintroduction of self-sustaining walleye populations. However, the weight of evidence suggests that while population level impacts do not appear to be occurring, individuals may remain at risk to sublethal effects such as liver tumors.

Insectivorous bird field evaluations showed no discernable effects on nesting behavior, clutch size, hatching success, or deformity.

Chemical levels of organochlorines in piscivorous birds remain sufficiently high to pose risks for at least reproductive impairment and deformities. While the historical levels of PCBs and DDE clearly impacted these birds at the individual and population level, some species (e.g., double-crested cormorants) within the bay have experienced substantial population increases. However, persistence of abnormal development within the area indicates that some level of risk remains for all piscivorous bird species.

Elevated mercury and organochlorine levels in prey continue to pose risk to survival and reproduction of carnivorous birds in zones 1 and 2 of Green Bay. The reproductive rates of nesting bald eagles in these zones appear depressed relative to both inland areas as well as other areas within the Fox River and Green Bay.

Based upon the estimated dietary intakes, PCBs are estimated to be sufficient to cause survival or reproductive impairment to piscivorous mammals.

3.2.6 Green Bay Zone 3A

In summary, the results taken in total suggest that concentrations of total PCBs are at sufficient levels to cause, or potentially cause, risk to benthic invertebrates, benthic fish, pelagic fish, piscivorous birds, carnivorous birds, and piscivorous mammals. There were no data to evaluate insectivorous birds. Mercury concentrations are potentially causing risk to piscivorous birds. Concentrations of dieldrin are a potential risk for carnivorous birds and piscivorous mammals. Concentrations of arsenic, lead, and all o,p'- and p,p'- isomers of DDT and its metabolites were not found to pose risk to any assessment endpoint.

3.2.7 Green Bay Zone 3B

In summary, the results taken in total suggest that measured or estimated concentrations of total PCBs are at sufficient levels to cause, or potentially cause, risk to benthic invertebrates, pelagial fish, piscivorous birds, carnivorous birds, and piscivorous mammals. There are no data to evaluate insectivorous birds. Mercury concentrations are causing or potentially causing risk to benthic invertebrates, pelagial fish, piscivorous birds, and carnivorous birds. DDE concentrations are causing, or potentially causing, risk to pelagial fish, piscivorous birds, and carnivorous birds. Dieldrin concentrations are potentially causing risk to piscivorous mammals. Arsenic and lead concentrations are only of risk to benthic invertebrates.

3.2.8 Green Bay Zone 4

In summary, these results taken in total suggest that concentrations of total PCBs are at sufficient levels to cause, or potentially cause, risk to benthic invertebrates, pelagial fish, piscivorous birds, carnivorous birds, and piscivorous mammals. Concentrations of DDE (measured in tissue) are causing or potentially causing risk to pelagial fish and carnivorous birds. Concentrations of mercury are causing or potentially causing risk to piscivorous and carnivorous birds.

3.2.9 Ecological Risk Summary for PCBs Mercury, and DDE

Overall, PCBs, mercury, and DDE were the COPCs that most frequently exceeded risk thresholds for all receptors (human and ecological) evaluated and, therefore these three compounds are considered COCs and carried forward in the FS. This section presents selected representative reasonable maximum exposure (RME) HQs developed from the BLRA for PCBs, mercury, and DDE, although, as indicated above, calculated HQs were only one part of the weight of evidence evaluated in the estimation of risk. These risks are summarized in Table 3-1.

HQs exceeding 1.0 for PCBs in the river and bay are presented on Figure 3-4 and Figure 3-5, respectively. For sediment, total PCB HQs in all areas exceeded 1.0. Sediment PCB HQs were greatest in Little Lake Butte des Morts Reach and lowest in Green Bay Zone 4, and generally, sediment HQs in intermediate areas indicated decreasing HQs while moving downstream from the river into the bay. Alternatively, in both benthic and pelagic fish, total PCB HQs increased moving downstream in the river. Total PCB HQs for benthic fish were highest in Green Bay zones 1 and 2, and for pelagic fish they were highest in Green Bay Zone 3B. No benthic fish data were available, however, for Green Bay zones 3B and 4.

Carnivorous and piscivorous bird data were limited to select areas in Green Bay, but did suggest that adverse reproductive risk is occurring. Therefore, because of this potential risk and the limited data, exposure concentrations for areas with no data were estimated through modeling. HQs for piscivorous and carnivorous birds based on exposure modeling suggest that, for both bird types, reproductive risk is greatest for Green Bay zones 1 and 2, followed by Green Bay Zone 3B. No data were available for piscivorous mammals and, therefore, exposure was estimated through modeling dietary intake as was done for piscivorous and carnivorous birds. Similar to the reproductive risk found for birds, the calculated HQs for piscivorous mammals suggest that reproductive risk is greatest for Green Bay zones 1 and 2, followed by Green Bay Zone 3B.

HQs exceeding 1.0 for mercury in all areas evaluated are presented on Figure 3-3. As indicated on this figure, mercury concentrations in sediment are higher in the river than the bay, and the highest sediment concentrations in the river are found

in the Little Rapids to De Pere Reach. Mercury HQs for fish only exceeded 1.0 in three areas: Little Rapids to De Pere Reach, Green Bay zones 1 and 2, and Green Bay Zone 3B. Fish concentrations were highest in the Little Rapids to De Pere Reach. Based on exposure modeling, piscivorous bird HQs were highest in Green Bay zones 1 and 2, and all other areas had HQs of similar magnitude. For carnivorous birds, exposure modeling indicated that HQs are highest in Green Bay Zone 3B, followed by Green Bay Zone 4.

HQs exceeding 1.0 for DDT and metabolites in all areas evaluated are presented on Figure 3-6. DDT (in the form of DDE) HQs are highest in the Little Rapids to De Pere reach, and HQs for DDT or its metabolites exceed 1.0 in surface sediment in all other areas evaluated except for Green Bay zones 3A, 3B, and 4. All HQs that exceeded 1.0 for tissues were concentrations of DDE, and all of these HQs were less than 10. DDE HQs for fish only exceeded 1.0 in three areas: Green Bay zones 1 and 2, Green Bay Zone 3B, and Green Bay Zone 4. DDE HQs in piscivorous birds exceeded 1.0 in Green Bay zones 1, 2, and 3B based on both measured and estimated tissue DDE concentrations; and HQs in carnivorous birds exceeded 1.0 in Green Bay zones 1, 2, and 4 based on exposure modeling. Estimated HQs for piscivorous mammals did not exceed 1.0.

3.3 Sediment Quality Thresholds

For both human health and ecological risk, the BLRA concludes that the greatest potential risk is from the PCBs that are found in the sediments of the Lower Fox River and Green Bay. For human health, the greatest risk comes from individuals who consume fish caught in the Lower Fox River and Green Bay. For the ecological receptors, the greatest risks were from total PCBs in the surface sediment, as well as PCBs in birds and mammals that rely principally on fish for food. Reducing total PCBs in fish by reducing the levels of total PCBs in the sediments was determined to be the most important means of reducing risks in the Lower Fox River and Green Bay.

The Fox River Bioaccumulation Model (FRFood Model) is a series of mathematical equations that describes a food web and the transfer of bioaccumulating contaminants within that food web. The model includes uptake routes from sediment and water to benthic infauna and ultimately fish, and the model was constructed so that it could be used to either predict fish tissue concentrations from a given sediment concentration, or to predict sediment concentrations from a given fish tissue concentration. The model was validated by running the model "forward;" that is, fish tissue concentrations were predicted from existing sediment concentrations and then compared to measured fish tissue concentrations. When the predicted concentrations were compared to the actual measured concentrations of total PCBs in fish collected in the Lower Fox River

and Green Bay, the results were highly comparable. Calibration of the FRFood Model indicated that all predicted fish tissue concentrations were within one-half order of magnitude of observed concentrations of total PCBs, except for yellow perch in the Little Lake Butte des Morts Reach. However, within this reach data were only available for one fish. As a result, the risk analysis carried forward in later sections of the FS focused primarily on walleye and carp, and not on yellow perch.

Human health and ecological SQTs were derived based on conditions present in the De Pere to Green Bay Reach (Green Bay Zone 1) (e.g., sediment organic carbon levels, organism lipid concentrations). As a risk management decision, it is assumed that SQTs derived for Green Bay Zone 1 will be applied to the whole Lower Fox River and Green Bay even if reach-specific or zone-specific water-to-sediment ratios may differ in part because the greatest human health and ecological risks are found in Green Bay Zone 1. Because of the uncertainty associated with the sediment-to-water ratio, SQTs may differ by an order of magnitude. For example, walleye NOAEC SQTs based on a sediment-to-water ratio of 10^{-5} are 8 times less than SQTs based on a sediment-to-water ratio of 10^{-6} and 25 times less than SQTs based on a sediment-to-water ratio of 10^{-7}. These derived SQTs are detailed below.

3.3.1 Human Health SQTs

To determine SQTs for the protection of human health, sediment concentrations associated with a variety of risk-based fish concentrations (RBFCs) were determined. The RBFCs were calculated for recreational anglers and high-intake fish consumers for reasonable maximum exposure (RME) and central tendency exposure (CTE) scenarios. For recreational anglers, the amount of fish consumed was determined from two studies of Michigan anglers, while for high-intake fish consumers, the amount of fish consumed was determined from a study of low-income minority anglers and a study of Hmong anglers. RBFCs were calculated for a cancer risk level of 10^{-5} and a noncancer HI of 1.0 for each receptor. The RBFCs were translated into SQTs using the FRFood Model. These SQTs are presented in Table 3-2.

SQTs for a cancer risk level 10^{-6} are 10 times less than the SQTs for the cancer risk level 10^{-5}, and the SQTs for a cancer risk level of 10^{-4} are 10 times greater than the SQTs for the cancer risk level of 10^{-5}. SQTs for the cancer risk level of 10^{-5} ranged from 11 to 677 μg/kg. Noncancer SQTs ranged from 28 to 1,128 μg/kg. For SQTs based on cancer and noncancer effects, the minimum SQTs were based on consumption of carp by the high-intake fish consumer under a RME scenario and the maximum SQTs were based on consumption of yellow perch by the recreational angler under a CTE scenario.

3.3.2 Ecological SQTs

SQTs calculated for the De Pere to Green Bay Reach (Green Bay Zone 1) are shown in Table 3-3. These SQTs are based upon levels of total PCBs in fish that either cause risk to the fish themselves, or to birds or mink eating the fish, or total PCB concentrations in the sediment that cause risk to benthic invertebrates. The SQTs for no observed adverse effects (NOAEC) to walleye is 176 μg/kg and for carp is 363 μg/kg. The only calculated SQTs that were lower than these were the SQT for benthic invertebrates and the SQTs for piscivorous mammals (mink). The benthic invertebrates threshold effect concentration (TEL) is a sediment PCB concentration of 31.6 μg/kg. The NOAEC SQT for mink is 24. The highest derived SQT is 5,231 μg/kg and this concentration was derived based on the LOAEC potential for deformity in common terns. SQTs based on NOAECs were up to 10 times lower than SQTs based on LOAECs.

3.4 Section 3 Figures and Tables

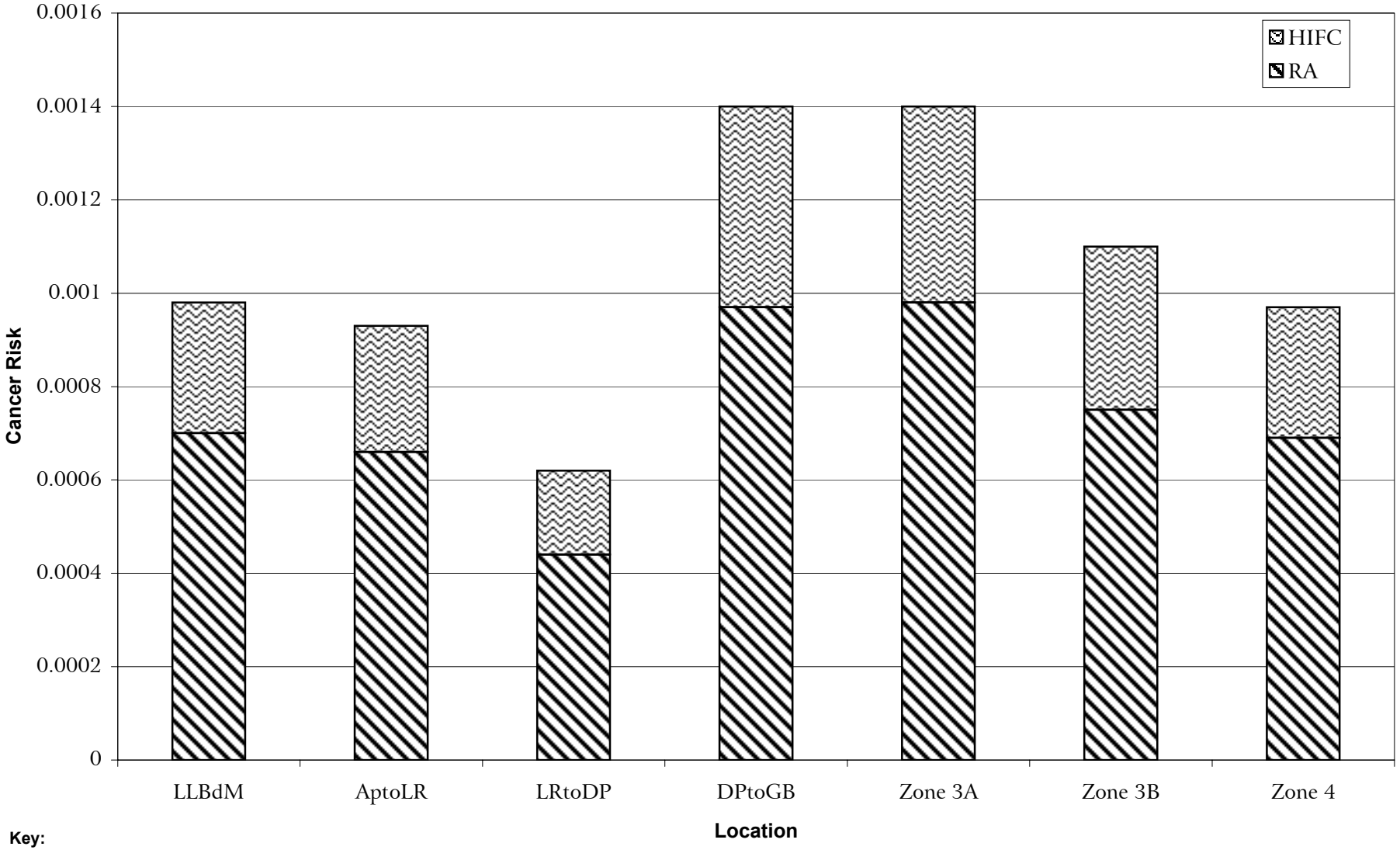
Figures and tables for Section 3 follow page 3-14 and include:

Figure 3-1 Maximum Cancer Risks for Recreational Anglers and High-intake Fish Consumers
Figure 3-2 Maximum Hazard Indices for Recreational Anglers and High-intake Fish Consumers
Figure 3-3 Selected Mercury HQs that Exceed 1.0
Figure 3-4 Selected PCB HQs that Exceed 1.0 for Little Lake Butte des Morts, Appleton to Little Rapids, and Little Rapids to De Pere Reaches
Figure 3-5 Selected PCB HQs that Exceed 1.0 for Green Bay Zones 1, 2, 3A, 3B, and 4
Figure 3-6 Selected DDT or Metabolite HQs that Exceed 1.0

Table 3-1 Ecological Risk Summary Table
Table 3-2 Sediment Quality Thresholds Estimated for Human Health Effects at a 10^{-5} Cancer Risk and a Noncancer Hazard Index of 1.0
Table 3-3 Sediment Quality Thresholds Estimated for Ecological Effects

[THIS PAGE LEFT INTENTIONALLY BLANK.]

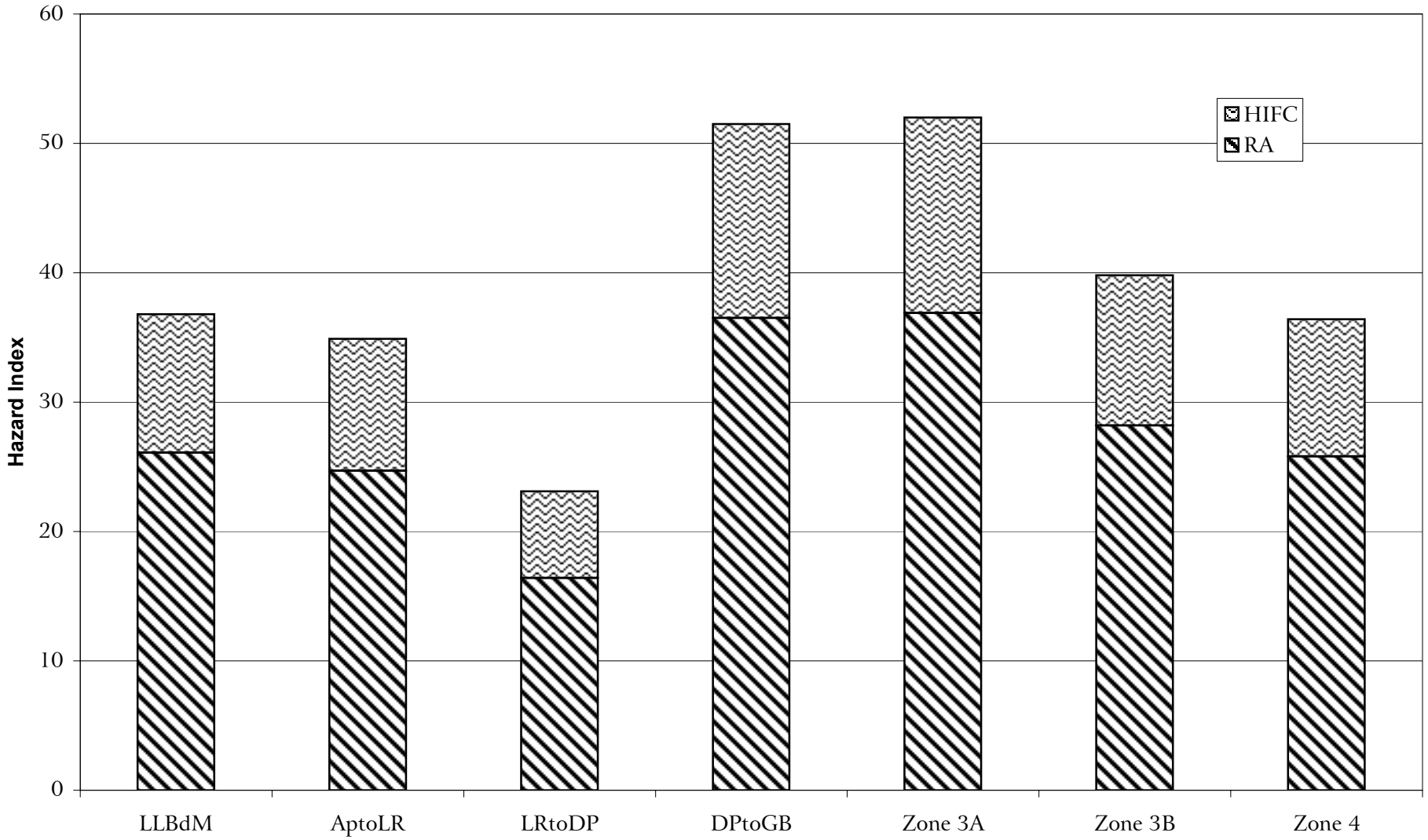
Figure 3-1 Maximum Cancer Risks for Recreational Anglers and High-intake Fish Consumers



Key:

RA - Recreational Angler
HIFC - High Intake Fish Consumer
LLBdM - Little Lake Butte des Morts
AptoLR - Appleton to Little Rapids
LRtoDP - Little Rapids to De Pere
DPtoGB - De Pere to Green Bay
Zone 3A - Zone 3A of Green Bay
Zone 3B - Zone 3B of Green Bay
Zone 4 - Zone 4 of Green Bay

Figure 3-2 Maximum Hazard Indices for Recreational Anglers and High-intake Fish Consumers



Key:

RA - Recreational Angler
HIFC - High Intake Fish Consumer
LLBdM - Little Lake Butte des Morts
AptoLR - Appleton to Little Rapids
LRtoDP - Little Rapids to De Pere
DPtoGB - De Pere to Green Bay
Zone 3A - Zone 3A of Green Bay
Zone 3B - Zone 3B of Green Bay
Zone 4 - Zone 4 of Green Bay

Figure 3-3 Selected Mercury HQs that Exceed 1.0

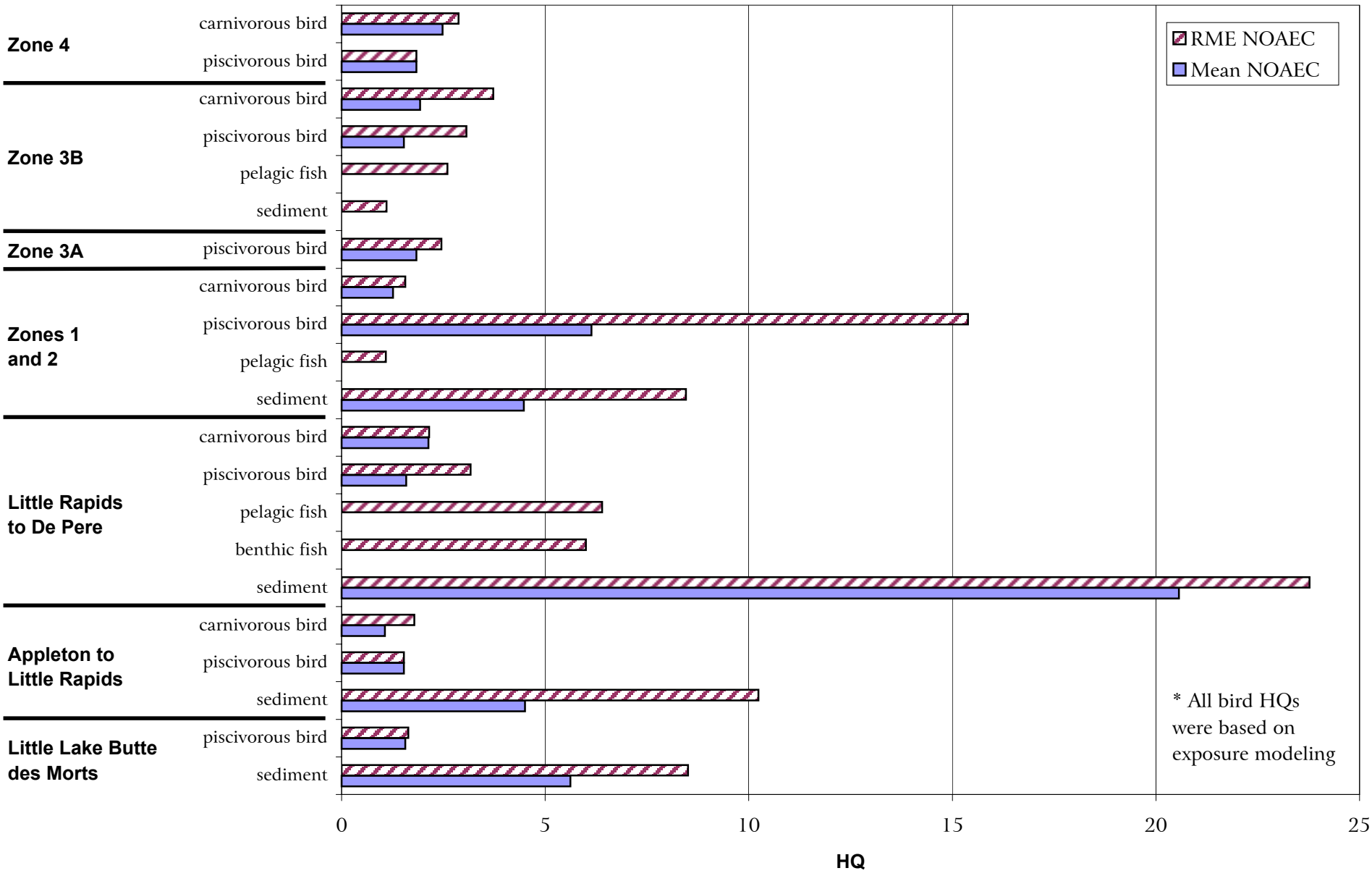


Figure 3-4 Selected PCB HQs that Exceed 1.0 for Little Lake Butte des Morts, Appleton to Little Rapids, and Little Rapids to De Pere Reaches

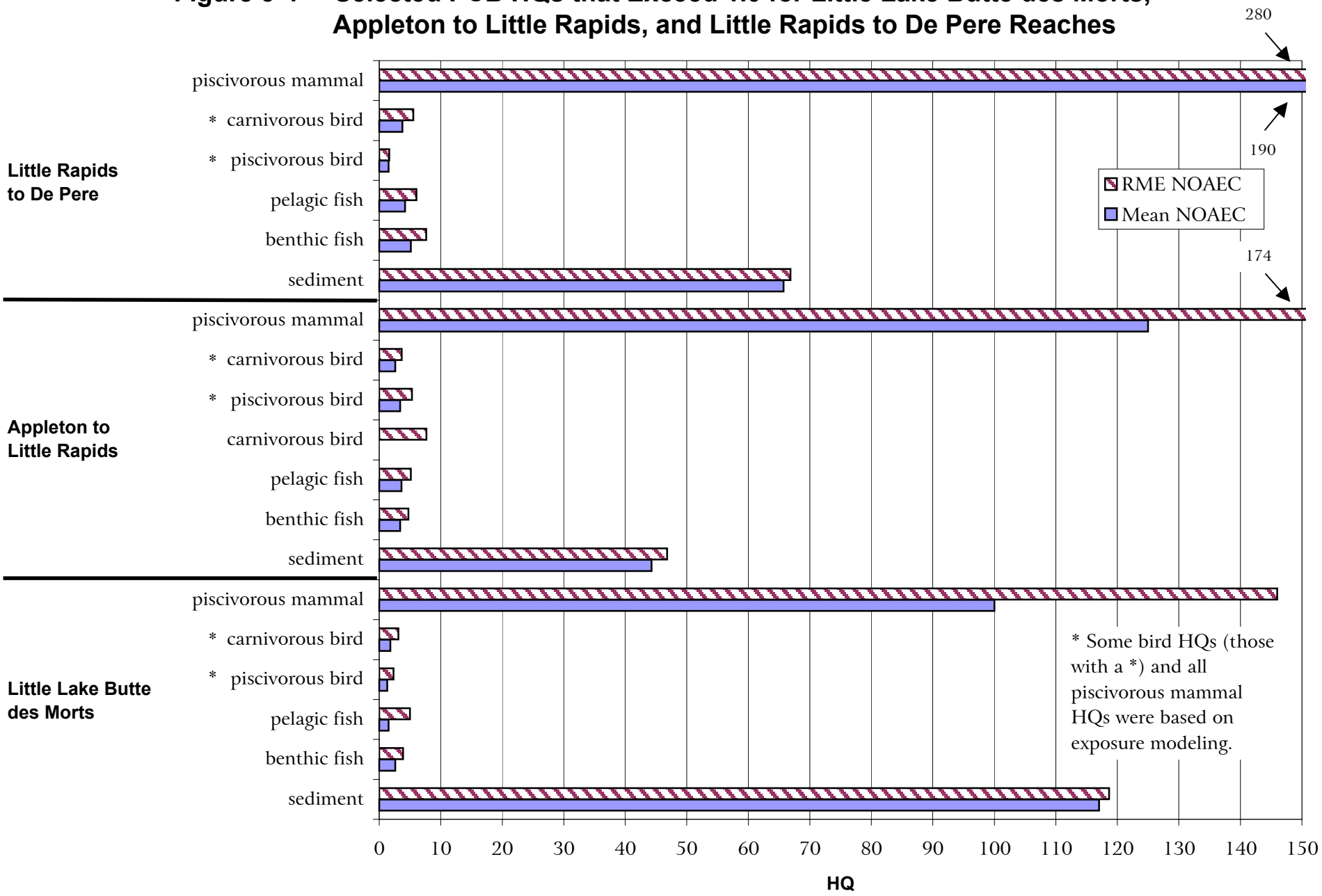


Figure 3-5 Selected PCB HQs that Exceed 1.0 for Green Bay Zones 1, 2, 3A, 3B, and 4

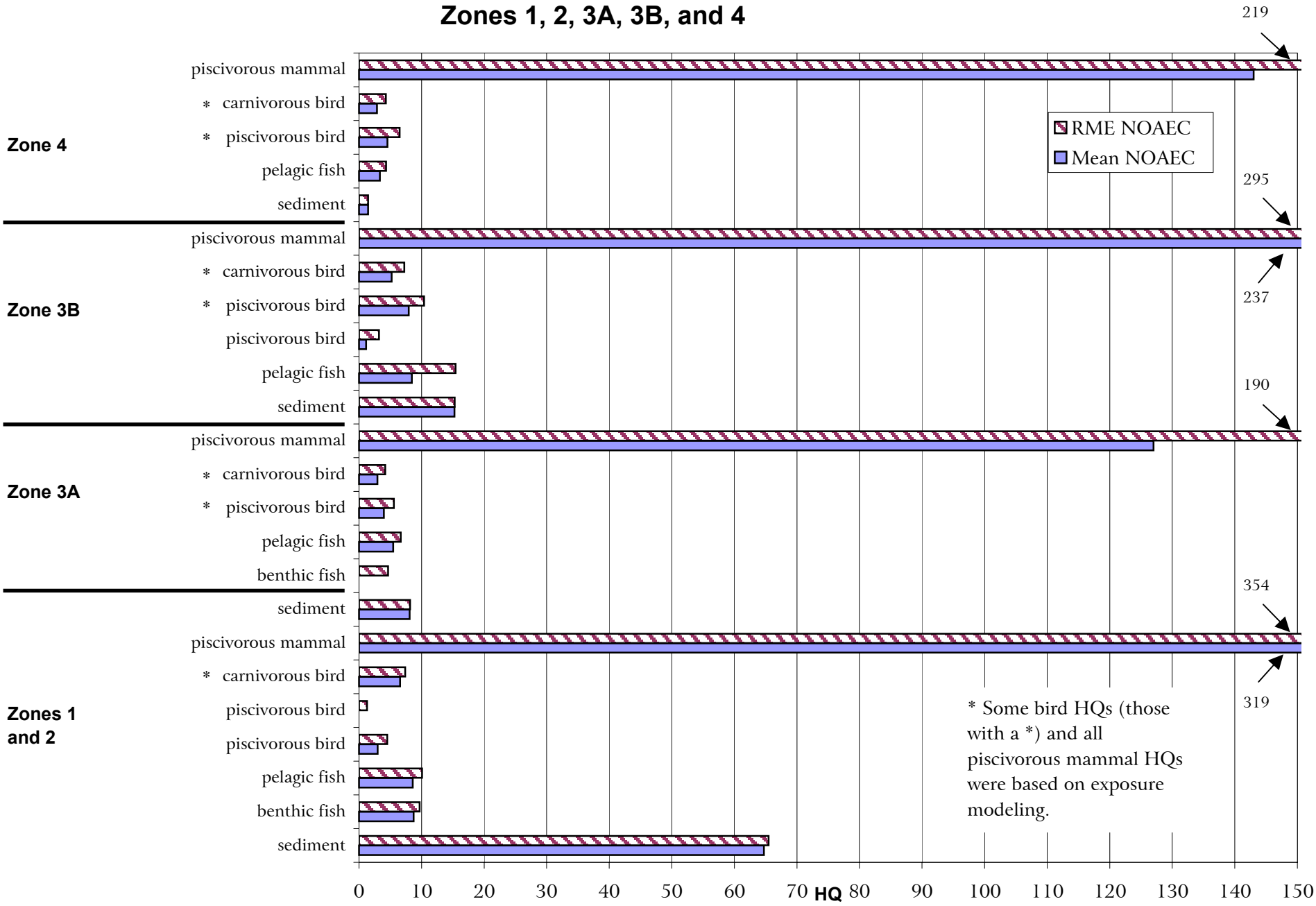


Figure 3-6 Selected DDT or Metabolite HQs that Exceed 1.0

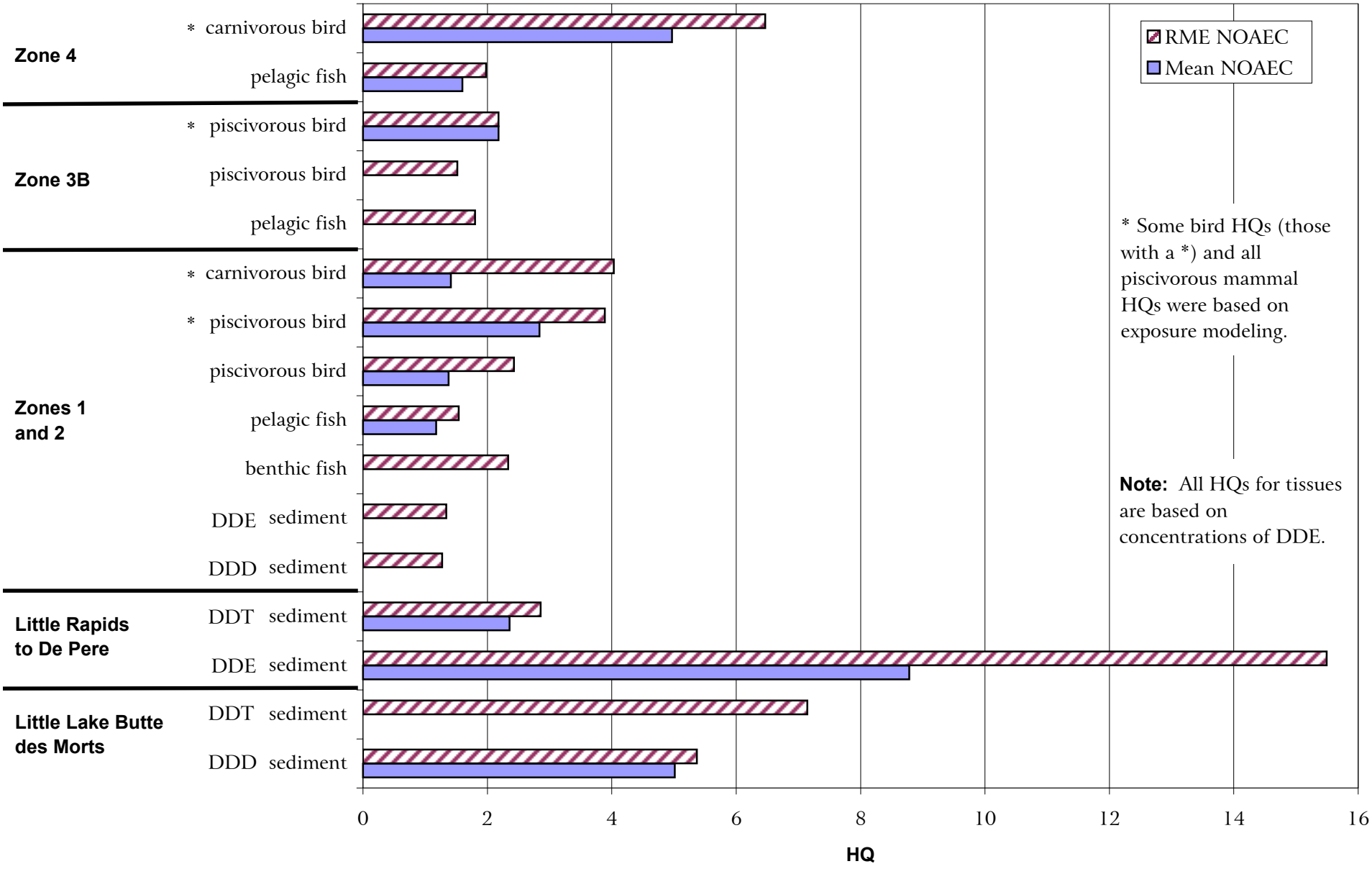


Table 3-1 Ecological Risk Summary Table

Location	Water Column Invertebrates	Benthic Invertebrates	Benthic Fish	Pelagial Fish	Insectivorous Bird	Piscivorous Bird	Carnivorous Bird	Piscivorous Mammal
Little Lake Butte des Morts	● *Mercury* ○ *PCBs*	● *Lead; Mercury; 2,3,7,8-TCDD; PCBs; DDD; DDT*	○ *PCBs*	○ *PCBs*	○ *PCBs*	○ *Mercury; PCBs*	○ *PCBs*	● *PCBs*
Appleton to Little Rapids	○ *PCBs*	● *Lead; Mercury; PCBs*	○ *PCBs*	○ *PCBs*	NA	○ *Mercury; PCBs*	● *PCBs* ○ *Mercury*	● *PCBs*
Little Rapids to De Pere	● *Mercury*	● *Lead; Mercury; 2,3,7,8-TCDD; PCBs; DDE; DDT*	○ *Mercury; PCBs*	○ *Mercury; PCBs*	NA	○ *Mercury; PCBs*	○ *Mercury; PCBs*	● *PCBs*
Green Bay Zone 1	○ *PCBs*	● *Arsenic; Lead; Mercury; PCBs; DDD; DDE*	○ *PCBs; DDE*	○ *Mercury; PCBs; DDE*	○ *PCBs*	○ *Mercury; PCBs; Dieldrin; DDE*	○ *Mercury; PCBs; DDE*	● *PCBs*
Green Bay Zone 2	● *Mercury*	● *Mercury; PCBs*			○ *PCBs; DDE*			
Green Bay Zone 3A		● *PCBs*	○ *PCBs*	○ *PCBs*	NA	○ *Mercury; PCBs*	● *PCBs* ○ *Dieldrin*	● *PCBs* ○ *Dieldrin*
Green Bay Zone 3B		● *Arsenic; Lead; Mercury; PCBs*		● *PCBs* ○ *Mercury; DDE*	NA	● *PCBs* ○ *Mercury; Dieldrin; DDE*	○ *Mercury; PCBs; DDE*	● *PCBs* ○ *Dieldrin*
Green Bay Zone 4		● *PCBs*	NA	○ *PCBs; DDE*	NA	○ *Mercury; PCBs*	○ *Mercury; PCBs; DDE*	● *PCBs*

Note:
NA - No data available.

Risk Conclusions Based on Hazard Quotients:

- No risk.
● - Risk.
○ - Potential Risk.

Risk Conclusions Based on Weight of Evidence:

- Site-specific receptor data suggest that there is no risk.
- Because of the federal listing of the bald eagle as threatened, it is concluded that potential risk is actual risk.

Table 3-2 Sediment Quality Thresholds Estimated for Human Health Effects at a 10^{-5} Cancer Risk and a Noncancer Hazard Index of 1.0

	Fish Parameters	Sediment Quality Thresholds			
	Fillet-to-Whole Fish Ratio	Recreational Anglers: Avgerage of Michigan Studies (West *et al.*, 1989; West *et al.*, 1993)		High-intake Fish Consumers: Average of Low-income Minority Anglers and Hmong Anglers (West *et al.*, 1993 and Hutchison and Kraft, 1994)	
		RME µg/kg	CTE µg/kg	RME µg/kg	CTE µg/kg
*Sediment Quality Thresholds for Risk of 10^{-5} **					
Carp	0.53	***16***	***180***	***11***	***57***
Walleye	0.17	***21***	***143***	***14***	***75***
Yellow Perch	0.17	***105***	***677***	***68***	***356***
Sediment Quality Thresholds for HI of 1.0					
Carp	0.53	***44***	***180***	***28***	***90***
Walleye	0.17	***58***	***238***	***37***	***119***
Yellow Perch	0.17	***276***	***1,128***	***175***	***564***

Notes:

* SQTs for cancer risks of 10^{-4} and 10^{-6} are an order of magnitude higher and lower, respectively.

RME indicates reasonable maximum exposure and CTE indicates central tendency exposure.

Sediment quality thresholds are bolded and in italics.

Table 3-3 Sediment Quality Thresholds Estimated for Ecological Effects

Species	Effect	Whole Fish Concentration (µg/kg ww)	Estimated SQT (µg/kg)
Benthic Invertebrates	Threshold Effect Concentration (TEL)	—	31.6
Walleye	NOAEC - fry growth and mortality LOAEC - fry growth and mortality	760 7,600	176 1,759
Carp	NOAEC - fry growth and mortality LOAEC - fry growth and mortality	760 7,600	363 3,633
Common Tern	NOAEC - hatching success LOAEC - hatching success NOAEC - deformity LOAEC - deformity	2,508 4,055 427 4,269	3,073 4,969 523 5,231
Forster's Tern	NOAEC - hatching success LOAEC - hatching success NOAEC - deformity LOAEC - deformity	2,399 3,879 408 4,083	2,940 4,753 500 5,003
Double-crested Cormorant	NOAEC - hatching success LOAEC - hatching success NOAEC - deformity LOAEC - deformity	814 1,317 139 1,386	997 1,614 170 1,698
Bald Eagle	NOAEC - hatching success LOAEC - hatching success NOAEC - deformity LOAEC - deformity	709 1,147 121 1,207	339 548 58 577
Mink	NOAEC - reproduction and kit survival LOAEC - reproduction and kit survival	50 500	24 239

[THIS PAGE LEFT INTENTIONALLY BLANK.]